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ABSTRACT

An evaluation of the community school mathematics program at five sites involved developing trial instructional materials, inservice training, and careful monitoring of implementation over six weeks. English and mathematics achievement instruments and cognitive development measures were administered to 201 pupils in grades two, four and six. Mathematics and language achievement varied significantly between sites. Students at all grades exhibited poor application problem solving skills, but computation, measurement and mathematical language abilities were superior to previously reported results. Mathematics achievement correlated highly with English reading and conservation and classification competence. Correlation between mathematics achievement and memory measures decreased from grades two to six, while correlations with measures of language and cognitive development tended to increase. Among the conclusions, a view is expressed that a locally developed textbook with an appropriate language load would enhance mathematics learning, particularly in remote rural areas where current teaching conditions and lack of materials interact with poor English skills to create an imbalance in achievement. (MP)

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School Maths In Papua New Guinea

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ABSTRACT

School Maths In Papua New Guinea

A case study was conducted reporting the evaluation of the the community school mathematics program at five sites in Papua New Guinea. Trial instructional materials were developed, teachers received inservice training and implementation was carefully monitored for a six week period. English and mathematics achievement instruments and eight measures of cognitive development were administered to a sample of 201 students in grades two, four and six.

Mathematics and language achievement varied significantly between the five sites. Students at all grade levels exhibited poor application problem solving skills while showing computation, measurement and mathematical language abilities superior to results reported previously. English reading and measures of conservation and classification competence were highly correlated with mathematics achievement. Correlations between memory measures and mathematics achievement decreased from grade two to grade six while correlations between measures of language and cognitive development and mathematics achieviment tended to increase.

The results indicated that the pilot student textbooks ameliorated to some extent the problems associated with non-native language instruction for children in remote areas and for grade two students in general. These groups showed greater achievement gains than older and/or more urbanized children. It was concluded that a locally developed textbook with an appropriate language load would enhance mathematics learning, particularly in remote-rural areas where current teaching conditions and lack of materials interact with poor English skills to create an imbalance in achievement.

School Maths in Papua New Guinea

If mathematical literacy is to address dual purposes of technological and village-level development, it is not sufficient for the education establishment to simply institute a selection procedure which identifies and promotes children who exhibit high "educational potential" while failing to adaquately address the needs of the vast majority of community school children. In developing a democratic society it is incumbent upon the education community to view their students as clients, to accept and to celebrate the individual's view of reality. This caution is of particular consequence to educators and polititions in developing countries responsible for implementing a Western style system of mass education.

Gay and Cole (1967), in their study of mathematics learning in Liberia, suggested that one of the primary characteristics preventing Kpelle children from succeeding in school was their unquestioning reverence towards knowledge possessed by adults. While such behavior may be necessary for survival in the traditional village environment, in school unquestioning reverence for the ideas of others is clearly inefficient. Without access to the scientific tool of initially reserving judgment while engaging in a process of objective analysis, the maze of new ideas encountered in school is destined to remain a mystery of unconnected facts.

The task of the teacher becomes that of helping the child adapt analogous knowledge from their own experience into the mathematical concepts incountered in school--translate folk-math into school-math. Since direct translation is rarely possible it is frequently necessary to extend and adapt traditional knowledge to help children define concepts that are not readily expressable in

local terms. The final objective remains, however, of instilling sufficient understanding of mathematics to enable people to successfully confront Western technology and defend themselves from it's effects if necessary.

Utilizing Locally Derived Knowledge

In order to signifiantly effect the quality of mathematics education these general pedagogical principles must be embodied in specific curriculum materials and practical teaching methods. How do educators identify those concepts that are relatively easy to model using experiences common to the culture of the students?

Saxe (1981) investigated the use of the Aksapmin body-counting system among children learning school mathematics and men operating trade stores. The capabilities of the traditional numeration system are currently being stretched to adapt to the press of new demands.

Scores of body counting systems are presently in use throughout Papua New Guinea. Each system defines a one-to-one correspondence between the counting numbers and specific points on the body generally above the waist. The maximum number that can be counted in one round is limited by the number of specific body parts identified in the system. The Aksapmin system contains a cycle of 27 points.

With the introduction of a money economy and decimal currency, trade in the market-place requires more frequent application of counting and operations on large numbers. Such environmental demands encourage enterprising adaptations of the current counting system.

For example Saxe reported that unschooled trade store operators invented a clever procedure for doing subtraction. They first "stored" the minuend (top number) by counting up to the appropriate body part. Next they counted the body-part number names up to the subtrahend (bottom number) while simultaneously retracing original the body part sequence. This process effectively instituted a consistent "stop rule". If "shoulder" means ten, we can subtract 2 by starting at the thumb on the right hand and pointing to each subsequent body part until we reach "shoulder" (ten). Next we move our finger to "upper arm" (nine) and say "thumb" (one) then to the "elbow" (eight) and say "forefinger" (two). We have effectively counted up to the subtrahend (forefinger--two) while counting down from the minuend (shoulder--ten). When we say the body-part number representing the subtrahend (forefinger--two) we institute the "stop rule" and look at current body position (elbow). The answer is "elbow" (eight).

Similar proceedures were found to be employed by children studying mathematics in the village community school. When understood by the teacher, such invented procedures rooted in the child's experience can provide a useful starting point for the development of symbolic algorithms. Ginsburg, Russel and Posner (1981) found examples of invented proceedures in their study of the development of arithmetic skills in African and American children. Analyzing protocols of children solving simple addition problems they concluded that children from the Ivory Coast experienced the same pattern difficulties as their American peers. In both groups invented procedures played a significant role in successfully completing computations.

One important implication is for teachers to help children invent

consistent ways of operating on already existing ideas as a basis for developing key mathematical concepts. For example, from simple counting children can develop the notion of exchange, place-value and operations with large numbers. Measurement using egocentric attributes (e.g., tall, thin, fast) leads to relative labels (e.g., taller, thinner, faster), unit measure (e.g., 2 metres, 25 kilograms) and eventually comparisons between unit measures (e.g., three centimetres longer). Often physical materials and pictures play a fundamental role in facilitating communication between the ideas in the student's head and those possessed by teacher.

Mathematics for Community Schools

Widespread implementation of Western style mass education has been in existence in Papua New Guinea for only about 20 years. A massive effort is still underway to build community (elementary) and high schools in the rural areas of the country. Attempts at developing a modern mathematics curriculum for use in primary schools was initiated in 1964 under the tutorship of Zoltan Dienes. Over the next ten years teams of mathematics educators developed various adaptations of the Dienes inspired syllabus, beginning with the kit-based Temlab program and culminating with the current Mathematics for Community Schools (MACS) program.

During this period of curriculum revision, the Territories of Papua and New Guinea became a unified independent nation. This event had profound effects on the whole education enterprise. The new government soon adopted the long range goal of instituting universal primary education by 1990 and the short term objective of localizing the primary teaching force. In 1970 the staff and inspectorate of the approximately 1500 community schools contained a

sizeable number of relatively well trained expatriates. By 1979 a completely localized staff of over 9000 teachers were servicing approximately 280,000 students at 2000 schools.

In effect a curriculum designed for a relatively well trained, supervised and equipped staff is now implemented by teachers with a maximum of ten years academic schooling with two additional years of teacher training, many working in unfamiliar cultures and extremely remote schools.

Attempts have been made to adapt the final version of the MACS program to local conditions by incorporating locally available instructional materials. However key lessons still depend on the availability of multibase blocks, attribute materials and sizeable quantities of paper products, none of which are readily available to the rural teacher.

Many teachers we talked to credited their college instructors with a conscientious effort to prepare them for the "reality" of life in the bush schools. It is clear however that these compensatory efforts on the part of motivated teachers are by no means universal or long lasting. A high degree of teacher "burn out" is reported, caused not only by the lack of teaching materials but also the constant frustrations associated with housing, health, salary and isolation.

As a consequence many MACS lessons are ineffectively presented or skipped altogether. There is a temptation on the part of the teacher to forego the preliminary manipulative experiences, so important for effective concept development, relying instead on symbolic "chalk-talks" followed by oral drills or sets of exercises. At the other extreme, we found teachers who drilled

children on base-5 operations, refusing to allow the class to move on until they have "mastered" this "modern-mathematics" objective.

Considerable misunderstanding surrounds the use of Dienes' "multiple-representation" model for learning as it applies to multibase arithmetic. Teachers tend to view operation with each base as a terminal objective, requiring children to master the symbolic process at each level. The original intent of the multibase model was to provide experience using various bases in order to develop the concepts of regrouping and place-value and introduce the algorithms for the four basic operations. This experience was suppose to lead to drill-and-practice with base-10 arithmetic and eventual mastery. Such misuse of the fundamental methodology associated with the MACS course (stressing mastery at each intermediate base), along with a serious lack of support materials, raises the question as to whether its inclusion in the current syllabus is, in fact, appropriate for the community schools in Papua New Guinea.

Indigenous Mathematics Project

The current study attempted to look at this question (among others) by developing a modest collection of instructional materials designed to enhance and simplify the teaching of number operations in the MACS course. A carefully observed trialling was carried out at five school sites representative of various cultures in the country.

The effort follows a three year series of studies carried out under the auspices of the Indigenous Mathematics Project (IMP). The IMP, begun in 1976, grew out of concerns for apparent unequal distribution across various

population subgroups of jobs in the wage-employment sector and positions in tertiary institutions (Kelly, 1977; Lancy, 1978). In recent years this issue has been, to some extent, subsumed by an increasing concern with the overall standard of education at all levels. The current debate is as much concerned with the definition of "standards" in the Papua New Guinea context as it is with assessing its imminent demise.

The implications for the community school system are twofold. First the curriculum must enhance the ability of children from areas with disproportionally few high school entrants to compete successfully for scarce secondary positions. Also as the country moves closer to its goal of Universal Primary Education (UPE), more and more children will return to the village after completing community school. Increased attention must be paid to the needs of this group of children who presently constitute 70% of the community school graduates. It is likely this percent will increase significantly over the next decade.

Case Study

It is with a view towards these concerns that the Indigenous Mathematics Project turned its attention from documenting variations in cross-cultural cognitive development (Lancy, 1980; Lancy, Souviney and Kada, 1981) to analyzing the effects of curriculum innovation on teacher behavior and student achievement.

Mehan (1978) and Bauersfeld (1979) point out the difficulties associated with interpreting classroom events in order that practical generalizations can be made which are transferable to other situations. We are cautioned not to

rely solely on static measures of classroom events (test scores, minutes of instruction, classroom arrangement, etc.) in our attempt to understand the learning phenomenon. If we are to have any hope of unravelling the complexities of the instructional process we must instead concentrate our attention on the interaction between these elements.

By carefully documenting the playing-out of events as they occur and seeking to reconstruct these events with the advice of the participants themselves, we are better able to understand what actually took place and how to interpret the relationships between teacher behavior, curriculum materials and student performance. This process of reflection and active negotiation of reality is useful in determining what people actually do as opposed to what they think or say they do.

Research Method: In the current study, classes at five sites were systematically observed in operation. We interviewed the teachers before and after each lesson to help reconstruct major events. Though the task proved to be exhausting for both the teachers and observers, the continual negotiation that took place enabled us to develop a far more complete understanding of the complex mathematics-classroom environment.

The goal was to look at potential ways of changing the classroom environment to enhance students' mathematical achievement. We were interested not only in raising mean scores, but also in reducing the variance of scores within the groups considered. We did not set out to alter the environment to enhance the development of a single segment of the population (i.e., the high achievers). Such an effort might significantly raise the mean achievement scores of the group as a whole though it would not necessarily reflect an

increase in achievement across even the majority of the subjects tested.

In light of the philosophy of the community school institution--that of preparing the majority of students to participate effectively in village life while providing basic academic training for those who go on to high school--it seemed fundamental to the entire enterprise that variance in student performance be considered as strongly as mean scores in evaluating relative success of instructional innovations.

In order to assist with the interpretation of systematic variations in achievement scores we felt it important to carefully document ongoing classroom events throughout the period of implementation. In looking ahead to the potential difficulties associated with the analysis of our test results, we anticipated that it would be useful to know what learning events may have contributed to an achievement gain. Such insight could prove to be even more important should no changes occure.

It is important to know why a curriculum works as simply knowing that it does work. Curriculum development work does not end with showing the desired achievement gains after a pilot implementation. To be effective, a curriculum must be adapted to local conditions which are certain to vary from pilot conditions in significant ways (i.e., teacher motivation and competence).

To provide effective advice to those responsible for helping teachers implement the curriculum, the researcher must know more than the probable increase of achievement under stated conditions. For example, it is useful to know how the actual lesson implementation differed from the instructions

given in the teacher's guide or inservice course. Such a measure indicates the extent to which the curriculum alters teacher behavior and suggests which fundamental assumptions are more safely made regarding teacher compliance with the proposed instructional methods.

This perspective puts the teacher at the center of the decision making process. The curriculum designer must answer the question of how much and what type of expert advice teachers will accept and apply in their classrooms. In answering such a question the researcher must do more than show significant achievement gains. Teachers should be reluctant to accept any curriculum that didn't offer achievement or efficiency gains. To ensure even minimal success in the complex school environment the curriculum must be adapted to the actual range of competence exhibited by the teaching force.

In light of discussion above and cognizant of the limitations such a design places on the generalizability of results, we opted to concentrate our effort and resources on five community sites.

A research associate was placed in each school to record the implementation efforts of the classroom teacher and the response of the class. A detailed field note-guide was developed (Levin, Gearhart and Souviney, 1980). The guidelines standardized the classroom observation procedures to insure as far as possible the collection of comparable data across the five sites.

Prior to each lesson the teacher was interviewed to assess his/her understanding of the objective materials, content and methodology. The intent was to determine the extent to which the pilot teacher-resource material

provided information necessary for conducting the lesson. Specific questions asked by the teacher were noted and subsequently addressed by the observer. Such a procedure allowed us to discover at what points teachers had difficulty understanding lesson objectives and instructions, yet limited the observer's opportunity to provide input. We made every attempt to avoid turning these briefing sessions into a formal inservice.

After the implementation of each lesson, a formal debriefing took place. This meeting generally occurred after school or in the evening and was held in conjunction with the briefing on the next day's lessons. The content of the debriefing centered around the teacher's perception of his/her effectiveness in meeting the lesson objectives. The relative success of the lesson was explored and an attempt was made to relate the experience to that of lessons already completed. Though a briefing and debriefing took place for every lesson, detailed implementation field-notes were taken in only about three lessons per week for each grade level. The other two lessons each week were devoted to observing language usage, classroom interaction variables and student interviews. This data is currently being analyzed and will be reported at a later time.

Assessment Instruments: In addition to collecting field notes, achievement and cognitive development measures were also administered. Each subject was tested three times to assess mathematics achievement immediately before and after the six week implementation period and again six weeks later as a measure of retention. Three equivalent versions (PMAT2, PMAT3, PMAT4) of the Primary Mathematics Achievement Test were administered as pre-, post-, and retention tests respectively. As a measure of English reading ability (READ), a multiple choice close-type sentence completion test and a standard dictation

passage (DICT) were administered at the time of the retention test (Souviney, 1980a; Elley, 1980).

A battery of eight cognitive assessment tasks were administered in a one-to-one clinical setting to a stratified random selection of subjects from each grade level. The tasks were designed to tap cognitive competencies ranging from simple memory measures to complex logical operations requiring a sophisticated use of language:

1. visual memory (objects)
2. visual memory (symbols)
3. memory space
4. conservation of number
5. conservation of length
6. double seriation
7. logical classification
8. class inclusion.

Grade two subjects were interviewed in tok ples (local vernacular) or Pidgin depending on their expressed language preference. Grade four and six used a mixture of tok ples, Pidgin and English, with an increasing tendency to the latter with older children. Tasks were adapted from English by the observer and a local informant using standard talk-back procedures.

Site Selection: Five community schools were selected from sites involved in previous Indigenous Mathematics Project studies (Lancy, 1978). For inclusion in the study each school had to enroll grades 2, 4 and 6; the staff had to express interest in being involved; two staff members had to

volunteer to participate in an inservice course and the trialling of instructional materials; the site had to represent one of the three categories of relative urbanization--extreme-rural, rural, urban; no two sites could be selected from the same province.

Stages of Project Implementation: The project was comprised of four stages:

1. Curriculum Development
2. Teacher and Observer Inservice
3. Curriculum Trialling
4. Retention Assessment

The first stage began in November 1979 with an evaluation of the current Mathematics for Community Schools syllabus. Lessons were selected from those normally taught in grades two, four and six during term 3. A set of student activity-books were developed around these lessons along with a limited number of manipulative aids and detailed teaching notes.

The second phase took place in April and June 1980. Two teachers from each school participated in a two week inservice course in Port Moresby. The objective of the course was to familiarize the teachers with the lessons and materials and to select one teacher from each school to actually use the materials during the trialling period. In June five visiting research associates arrived in Port Moresby. For two weeks plans for field-note organization and assessment procedures were discussed and trialled and the curriculum materials were reviewed.

In early July preliminary achievement and cognitive assessment instruments were administered by the research associates at each site. Instruction and classroom observation commenced on 14 July (the beginning of Term 3) and ended with post assessment on 22 August 1980.

The final stage began with a one week debriefing seminar immediately upon the return of the observers from the field. Draft field reports and recommendations were prepared. A final round of achievement testing was carried out in early October by the IMP staff.

Ethnographic Descriptions of Sites: Five community schools were selected from sites which cooperated with previous IMP cognitive research studies. Each site was evaluated according to its relative accessibility, student performance and provincial distribution. The sites selected offered a range of extreme-rural to urban settings with coastal and highland representation.

The first school (Levin, 1980) was situated in the Admirality Islands on a small island just off the north coast of Manus. It is surrounded by a superb lagoon protected by a reef from the open sea. It is approximately one kilometre by two kilometres in size with its highest point about two metres above high tide. Fish are plentiful and fresh vegetables can be obtained at the twice weekly market on the mainland. The current population is approximately 250 people.

Commercial flights arrive in Lorengau, Manus several times each week. An additional three hour canoe trip is required to arrive at the site. Accessibility was classified as difficult in that equipment and personnel had

to travel by expensive (35 kina each trip) private canoe, subject to favourable weather conditions.

The school was constructed in the late 60's of locally produced cement blocks with louvered windows and corrugated iron roofing. The building is situated on the public common area along with the health aid-post, teachers' houses and a public club (a provincial experiment in village-level alcohol sales). The site consists of three classrooms and a small office. The school initiates intake every other year so the student population consists of grades one, three and five one year, and two, four and six the next. For some unexplained reason there was no intake in 1979, so in 1980, grades one, four and six were available. We decided to use the school anyway since it had available more of the grade levels with which we were working than the other schools under consideration in the region.

Schooling in the area was initiated in the 1920's by the Catholic Mission at Bundralis only a few kilometres away on the mainland. Primary schooling began at the island site in the 1950's. A full compliment of grades (1-6) was instituted less than ten years ago. Currently there are two teachers serving about 90 students in three grades. Nearly all school age children on the island (and some family members from the mainland) attended school. Most adults under 40 have had some schooling. The local vernacular was the first language of all the children on the island. Pidgin was widely spoken as, to a lesser extent, was English. Manus enrollment figures for 1979 show approximately 61% of the 7-12 year old population in school.

The second site (Gearhart, 1980), even more remote than the first, was accessible only by small aircraft servicing the local mission at Tekin or the

government station at Aksapmin, West Sepik Province. It required an additional three hour walk through lush mountain vegetation to reach the school. The school, playground and gardens were terraced into the side of the hill next to a small river at an altitude of about 2000 metres.

The buildings consisted of six classrooms, an office and several teachers' houses, all constructed of bush materials except the headmaster's house. The school, built less than ten years ago, housed five teachers and 126 students in grades two, three, four and six (two second grades). Though it is difficult to make accurate estimates regarding the percent of school age cohorts attending primary school, we figure less than 50% of those under 18 years have attended school, with a somewhat smaller percentage completing grade six. West Sepik 1979 enrollment figures show approximately 62% of the 7-12 year old population in school.

The local vernacular (Oksapmin) was the first language of all the children. Pidgin was increasingly spoken as local men return from work on a tea plantation near Mount Hagen. English was spoken only at school.

The community surrounding the school consisted of several small hamlets with a total population of about 1800 people. The men cleared kaukau and taro gardens on the almost verticle slopes of the mountains. When money was available, rice and canned mackerel were available in the trade stores to supplement the diet. Though many domestic pigs could be seen roaming the hillsides, they were eaten primarily at celebrations minimizing the usefulness of this source of protein. Many children showed signs of protein deficiency and almost constant colds due to the damp, cold climate and scanty clothing.

The third site (Johnson, 1980) was located in the Southern Highlands, three hours drive from Mount Hagen. Though this school currently can be reached by road throughout the school year, this has only recently been the case. The school was built in 1966, providing the first schooling opportunity for the 15 villages in the area. The site consisted of seven semi-permanent classrooms, two bush materials classrooms, an office and storeroom, several teachers' houses, a large playground, gardens and a fish pond. Eight teachers serviced 291 children in grades one through six (two each of grades one and two). In the villages within one hour walking distance an estimated 90% of the school age cohorts attended school. The figure dropped dramatically for more remote villages. Over the whole region less than 50% of the children completed grade six. Southern Highlands 1979 enrollment figures show approximately 51% of the 7-12 year old population in school.

The local vernacular (Imbonggu) was the first language of all the children. Some Pidgin was used in the villages. English was reserved almost exclusively for school. The primary food staple was kaukau and greens supplemented with rice and tinned fish, if money was available from basket-making or construction work. The only local source of protein was a few fish caught in streams and domesticated pigs which were eaten primarily at clan celebrations. Children continually showed symptoms of colds though school attendance was high.

The fourth school (Rowe, 1980) was situated approximately one-half hour drive from Mount Hagen in Western Highlands Province. It was built on a flat plain at an altitude of about 1800 metres. The area had excellent soil and growing conditions which provided a wide range of fruits and vegetables for sale and local consumption. The area boasts some of the finest coffee

plantations in the country as well. Ancient drainage ditches built to enhance agriculture productivity, reportedly among the oldest in the world, have been discovered close to the school.

The school was originally built at a nearby site in the early 1960's. The current structure, built in the mid-1960's, consisted of two permanent structues containing five classrooms, an office and a store room; three bush material classrooms; several houses for teachers; two gardens and a number of coffee plants. It was connected to Mount Hagen by an all weather road and frequent public motor vehicle (PMV) service. The school was relatively well equipped with a duplicating machine, a modest library, and a telephone. Two additional permanent classrooms were currently under construction as well. The students and teachers grew vegetables and coffee to sell in the local market in order to generate additional money for school equipment and activities. Eight teachers serviced 233 students in grades one through six (two each of grades one and six).

The local vernacular (Melpa) was the first language of all the children in the area. Considerable Pidgin was spoken in the community as well. English was rarely spoken outside school. Approximately 60% of the children in the catchment area attended school. Western Highlands 1979 enrollment figures showed approximately 45% of the 7-12 year old population in school.

The final school (Lineberger, 1980) was situated in a suburb of Port Moresby. It was built when the Tokoara subdivision was constructed in the mid-1960's. It consisted of 12 permanent classrooms built on posts with louvered windows, wood floors and corrugated metal roofs. It was the only site that had full city services --electricity, running water and plumbed toilets. The

teachers lived in similarly constructed houses surrounding the school. The entire site was enclosed by an eight foot woven-wire fence to reduce vandalism. The school was well equipped with a duplicating machine, small library, modest teaching aids and textbooks, a telephone and a canteen which provided hot lunches for students at a modest cost.

The community was comprised of government and industry personnel who were products of scores of villages throughout Papua New Guinea. Most the the children were from upwardly-mobile parents who speak English at home and were multilingual when they begin school. Most were able to speak English, mother's and/or father's tongue, Motu and/or Pidgin. English was widely spoken on the playground except by the youngest children.

Eleven teachers serviced 408 children in grades one through six (three grade ones, two each of grades two, three and four). A relatively large school, it serviced almost all of the school-aged children in its middle class catchment area. National Capital District 1979 enrollment figures showed approximately 62% of the 7-12 year old population in school.

Site Summary: The uniqueness of each site was the reflection of a multitude of environmental variables. Language and cultural factors, staff experience and motivation, availability of instructional materials, accessibility and frequency of inspections, students health and family support all contributed to the relative effectiveness of each school in promoting student achievement. The five communities ranged widely in acessibility, language, culture and type of economy. The schools reflected these variations as well as substantial differences in the physical classroom environment. Table 1 summarizes various characteristics of the five sites.

Insert Table 1 about here.

Though the schools exhibited a wide variance in environmental and cultural factors, mathematics instruction at all sites followed the same syllabus for a similar number of minutes each week. The level of teaching experience tended towards the pattern of least experienced teachers being assigned to the most rural schools. The teachers actually involved in the trialling of the pilot materials had roughly equivalent training and experience and achieved similar scores on various measures of cognitive ability.

The reader is reminded that the sites selected are not necessarily representative of the approximately 2000 schools in the country. Comparisons with other schools will be meaningful only to the extent to which they are similar to those reported here.

Student Population: Three classrooms were selected at each site (except Manus), one each for grades two, four and six. If a school had more than one class of any of the three grades, one was randomly selected to participate in the trialling. One of the duplicate classes at four sites participated in the achievement assessment to provide a basis for comparing patterns in achievement. Only the island site in Manus was unable to provide a complete complement of grade levels. Table 2 gives a summary of student ages for classes involved in the study.

Insert Table 2 about here.

In general there were fewer girls than boys, especially in the upper grades. There seemed to be a more even balance in more urban settings. The children were of average health for the regions in which they resided. Attendance was reasonably consistent throughout the year. Subjects with excessive absences were dropped from the study.

The project staff were particularly impressed with the motivation and eagerness exhibited by the students at every site. Even under adverse conditions--in the highlands cold, damp, dark classrooms with inadequate seating; in coastal regions, hot, humid absolutely still days--the children were almost without exception wide eyed, hard working and graciously forgiving.

Teacher Selection: Our design called for extensive classroom observations and frequent interviews with each teacher. One teacher at each site would also be responsible for teaching mathematics to three classes of children.

Our initial concerns regarding teacher reluctance to participate were quickly dispelled after discussing the proposal with each school staff. Several teachers expressed interest in participating. It was clear that access to improved instructional aids and the potential for professional development contributed to their enthusiasm.

Two teachers from each of the five sites were selected to participate in a two week IMP sponsored inservice course at the Port Moresby Teacher Inservice College. One teacher from each school was eventually selected to implement the trial materials. The individuals agreed to give up their Easter holiday and National Inservice Training Week activities in order to participate.

The level of teaching experience for the ten participants (eight men and two women, all in their twenties and early thirties) ranged from 4 to 11 years. Each had completed two years teacher training after provincial high school (grade ten). The group as a whole were seen as relatively successful teachers by their supervisors, spoke English with varying degrees of ease and planned to remain in the field for the foreseeable future. All but two participated actively in the two week inservice course. One arrived three days late due to transportation difficulties and the other missed the first week due to a death in the family.

Instructional Methods and Materials: The IMP staff developed over 30 pilot lessons for grades four and six and 60 lessons for grade two. Each school scheduled five periods of IMP mathematics per week. Two extra math classes were scheduled in the afternoon as well, providing extra time for completing assignments if necessary. All the lessons were scheduled to be 30 minutes in length giving a total of 210 minutes instruction per week. In order to minimize the teacher effect plans called for one teacher to provide mathematics instruction for three classes (grades 2,4, and 6) at each site.

Many of the lessons were adapted from the Mathematics for Community School teacher's guides. Several changes in emphasis were incorporated into

the set of trial activities. In order to allow more time for the development of base-10, place-value and number operation concepts, work with multibase arithmetic was eliminated and the number of logical-relations activities reduced. New sequences of structured activities were introduced to provide a firm base for developing algorithms for whole number operations (Britt, 1981; Souviney, 1980b, 1980c, 1980d, 1980e; Souviney, Keyser, Sarver, 1978). Classification activities were adapted to utilize specially produced attribute materials (kina cards).

A range of lessons was selected for inclusion. Some required extensive use of learning aids such as base-10 materials with the students organized in small groups. Others involved large group discussions or independent seat work. Our intent was to document the teachers' success in implementing lessons of various configurations and subsequent student response.

Several innovative features were incorporated into the trial materials. Student activity books were produced for distribution on a one-to-one basis. A step-by-step guide was prepared for each lesson in order to assist the teacher's programming efforts. A minimal set of inexpensive learning aids was designed and produced to provide the concrete experiences called for in the Teacher's Notes.

Physical materials designed to offer optimal perceptual input for the novice learner were considered vital in the multilingual community school environment. It was envisaged that teachers who had difficulty communicating directly with children from different language groups could use structured teaching aids to help translate the mathematical concepts and processes rather than rely ing exclusively on symbolic examples and chalkboard drills. Three

primary areas of mathematics content (excluding geometry) were addressed using various concrete aids:

1. Number and Operations (Base-10 materials, coins, squared paper)
   a) Place-value
   b) Addition
   c) Subtraction
   d) Multiplication
   e) Division
   f) Problem Solving

2. Measurement (metre sticks, balances, trundle wheels)
   a) Estimation
   b) Comparison
   c) Length, Area, Mass, Volume, Time, Velocity
   d) Metric System
   e) Problem Solving

3. Classification and Logical Thinking (Kina Cards)
   a) Likeness and difference relations (attributes)
   b) Logical connectives (and,or)
   c) Negation (not)
   d) Union, Intersection
   e) Class Inclusion
   f) Problem Solving

The philosophy underlying the MACS course as well as the IMP trial materials is one of active student participation in the learning process. The

processes can best be described as one of guided discovery whereby learner activity constructs order out of interactive experiences. The task of developing the considerable amount of mathematical knowledge in the limited time allowed is rationalized by the consistent, unobtrusive aid of the teacher and the structure of the curriculum itself.

Achievement Results: Several measures of mathematics and language achievement were administered. Though statistically significant differences were found between schools, the patterns of differences were not consistent.

In mathematics achievement, the highland schools generally showed lower achievement levels than those in coastal areas. Though English reading competence was highly correlated with mathematics achievement ($r=0.76$), the site with the highest reading achievement scored second or perhaps third in overall mathematics achievement. The West Sepik subjects, who scored the lowest on most measures, performed admirably on the oral dictation exercise. Table 3 shows the pooled grade four and six mean achievement results for the five sites.

Insert Table 3 about here.

The two most rural sites (West Sepik and Manus exhibited little similarity in their achievement profiles, suggesting that proximity to provincial education services may have only a contributing influence on student achievement.

The variance associated with the pre-test (PMAT2), post-test (PMAT3), and the retention-test (PMAT4) offered additional encouragement with regard to the success of the implementation. The standard deviation decreased from 17.2 for PMAT2 (pre-test) to 16.0 for PMAT3 (post-test). Since the mean increased and the top quartile did not change significantly, we are left with the conclusion that the subjects on the lower end contributed more to the mean gain than those at the top.

Insert Table 4 about here.

It can be argued that subjects receiving the lowest scores on the pre-test could be expected to show greater gains since they are confronted with relatively simple previously missed items while the students at the top are confronted with more difficult missed exercises. The fact that grade two subjects gained on the average about twice as many percentage points from PMAT2 to PMAT3 as those in grade four and six, could be interpreted to support this contention. However, though the mean continued to increase from PMAT3 (post-test) to PMAT4 (retention-test) the standard deviation increased to SD=16.5, implying a broadening of achievement spread during the retention period, which suggests a trailing off in achievement for the poorer students.

Though it appears that IMP's involvement at the five sites positively effected overall mathematics achievement the question remains as to whether to attribute this growth to the curriculum, the preliminary inservice course, or simply the motivation associated with the presence of the full-time observer. We suspect the combined effect of these factors contributed to the observed

surge in the achievement.

A significant difference was found between sites based on pooled grade four and six PMAT2 results ($F=1.73$, $p<.001$). The five sites divided into two homogenous subgroups with the SHP, MP and NCD sites achieving significantly higher than the WHP and WSP sites. Similar results were found for READing ($F=11.2$, $p<.001$) though the homogenous subgroups differed slightly. Significant differences were found between sites with regard to DICTation scores as well ($F=26.5$, $p<.001$) though surprisingly the WSP site ranked above all the other sites. Perhaps the extensive use of NBC radio broadcasts throughout the year at this extremely remote site had its effect on the results of this measure of ability to transcribe oral dictation.

It is interesting to note that due to the results of prior studies we expected the NCD and MP sites to attain higher achievement scores than the highland sites. The SHP school, however, consistently outperformed all other sites in mathematics achievement.

As expected reading achievement was higher in the coastal regions than the highlands sites. Though there is a reasonably high correlation between PMAT2 and the READing and DICTation scores ($r=0.76$ and $r=0.80$ respectively) the relationships are by no means linear. SHP achieved higher means in math (significantly in grade six) than NCD, while the situation is reversed for READing and DICTation results.

English language competence seems to have a strong positive effect on mathematics achievement up to an unspecified threshold, beyond which some other factor (possibly reasoning or problem solving ability) comes into play.

Improving language skills in the lower grades may therefore elicit a greater effect on mathematics achievement than in the upper grades where threshold language skills necessary to support mathematics learning are more likely to have been attained. This contention certainly deserves further attention and could provide a basis for practical solutions to persistent instructional problems. More stress on the explicit development of mathematical vocabulary and appropriate grammar would seem central to any effective primary syllabus.

Item Analysis. Mean achievement results are only useful for comparing sites, grade levels and overall changes in achievement. In order to evaluate understanding of specific mathematics content it is necessary to look at individual test items and their relationship to subject-matter topics. PMAT items can be grouped under four content strands:

1. Measurement (11 items)
2. Number and Operations (36 items)
3. Mathematical Language (7 items)
4. Problem Solving Applications (8 items)

Computing achievement growth in each of the four content categories offers a clearer picture of the learning profile. Table 5 gives the mean percent of correct responses for PMAT2 and PMAT3 by content strand.

Insert Table 5 about here.

The results show that this group of students are far more competent at

items involving measurement, number operations and mathematical language than those involving problem solving applications. Also, significant achievement gains are attained at all grade levels for all strands except problem solving. These results follow a similar pattern to the one reported by Carpenter, et al (1980) in their review of the Second National Assessment of Educational Progress conducted in the United States. They concluded that the students tested performed adequately on skill exercises, but were unable to demonstrate even the most basic prolem solving abilities.

Further clarification is provided by Figure 1 which shows the mean percent of correct response on test items designated as grade level objectives. Of the 62 PMAT exercises, 33 addressed grade-two objectives, 31 grade four and 37 for grade six. (Some objectives overlapped grade levels due to the reintroduction of selected concepts at later grade levels.)

Insert Figure 1 about here.

Though substantial increases in achievement are noted across the six week trialling period, a different trend becomes apparent. Grade two children achieved a mean of approximately 71% on appropriate grade level objectives on PMAT3. Grade four achieved a mean of about 61% and grade six 58%. We conclude that in upper grades as the content increases in difficulty overall achievement on grade level objectives decreases.

Finally Figure 2 shows the percentage of children attaining an arbitrary mastery level of 80% on grade level objectives. Results are presented for

PMAT2, PMAT3 and PMAT4.

Insert Figure 2 about here.

The percentage of students attaining grade level expectations decreases from grade two to grade six (PMAT4: 45%--grade two; 34%--grade four; 26%--grade six). The percent attaining mastery consistently increases over the three testing periods (11 July, 22 August, 3 October). These results are relatively encouraging in the PNG context when compared to previous results (Roberts and Kada, 1979; Edwards and Bajpai, 1979) that reported as low as 4% mastery level attainment for grade six students.

Further insight is offered by analysis of mathematics and language achievement data collected from an International Primary School in Port Moresby and an elementary school in California, United States of America. Though conclusions should not be drawn from such a limited sample, the results offer additional perspective for interpreting the Papua New Guinea data.

In order to make meaningful comparisons the data has been organized according to "years of schooling" as opposed to grade levels. Almost all International Primary and United States elementary school children attend a year of preparatory or kindergarten prior to grade one. This is not the case with Community School children. For example, four years of schooling corresponds to grade three for the International Primary and United States schools and grade four for Papua New Guinea community schools.

Insert Table 6 about here.

Overall, children at the International Primary and Community School sites answered 69.5% vs. 64.0% of the mathematics exercises correctly. Reading means were 96.5% and 80.7% respectively. Comparisons between the Papua New Guinea and United States sites follow a similar pattern, though no language assessment was administered at the California site.

Insert Table 7 about here.

On an average, United States students correctly answered 69.0% of the PMAT2 items, while the Community School students achieved a mean of 58.5% correct. While we did not test for significance, the small difference in achievement means seems far more encouraging than previous crosscultural comparisons would lead us to believe.

The important difference here is that we are comparing "years of schooling" as opposed to grade levels. If we took into account the number of International Primary and United States elementary school children who attend one or more years of pre-school prior to preparatory or kindergarten, we suspect that the differences in achievement would be even further reduced. It will be of considerable interest to review the progress of North Soloman children participating in the Tok Ples Schools Project (Kemelfield, 1981).

These children will have the benefit of two additional years of vernacular schooling prior to starting grade one.

Cognitive Competence, Language and Mathematics Achievement: A strong relationship appears to exist between cognitive competence, English language ability (the language-of-instruction) and mathematics achievement. Correlations between mathematics (PMAT2) and COGTOT (a linear combination of the five conservation and classification measures), READing and DICTation are $r = 0.63$, $r = 0.76$ and $r = 0.80$ respectively ($n = 201$). Memory measures afforded somewhat lower correlations with mathematics achievement (visual memory: objects--$r = 0.28$; symbols--$r = 0.22$, and memory-space--$r = 0.42$).

Memory skills seem to play a more significant role in the early years since the correlations between memory measures and mathematics achievement scores diminish with years of schooling. The opposite seems to hold for language and cognitive competence. As the mathematics content becomes more complex and the symbolic load increases, more successful students seem to rely less on their visual memory skills and more on their language abilities.

Insert Table 8 about here.

A multiple regression analysis was computed using site, sex and grade as independent variables and PMAT2 as the dependent variable. The memory, READing and COGTOT variables were then regressed on the residual of PMAT2. The "status" variables accounted for 81.3% of the variance in PMAT2 and the "cognitive" variables accounted for 10.7% of the residual ($n = 201$). Together

the variables accounted for over 92% of the variance in PMAT2. COGTOT reached significance ($p = 0.013$). Though READing did not reach significance, it can no be counted out since it is highly correlated with COGTOT (Souviney, 1980f).

Classroom Observation Summary: In addition to administering the cognitive and achievement instruments described above, classroom observation field-notes were compiled at each site. Significant classroom events were documented over the entire six week trialling period (Gearhart, 1980; Johnson, 1980; Levin, 1980; Lineberger, 1980; Rowe, 1980). A review of observers' notes (Miller-Souviney, 1980) identified several problems which seemed to detract from the quality of instruction at the majority of sites. The problems fell into three general categories:

1. Instructional materials
2. Classroom management
3. Subject matter content.

Instructional Materials: All the teachers had some difficulty coordinating the various instructional components associated with the lessons. Each teacher responded to the challenge in his/her own way and with varying degrees of success.

The most prevalent problem involved the preparation, distribution and storage of learning aids. Those aids prepared by the IMP staff (die-cut cardboard base-10 materials, coins and kina cards, measurement devices and squared paper) were all shipped to the sites beforehand. These materials were for the most part punched-out by the teacher and packaged in envelopes prior to the beginning of Term 3. No serious problems occurred.

Where difficulties did occur however, was with materials designed to be prepared by the children themselves. Picture cards designed to introduce time-seriation proved to be too difficult for second grade children to trace or draw. The resulting lesson took far longer than was justified. Attempts to circumvent the problems by using words instead of pictures were successful at two of the sites. One teacher reproduced copies of the worksheet for each student and the lesson proceeded as planned. Duplicating machines were available however at only two of the schools. Two teachers suggested that sequence stories could be drawn by the children during art or language class and used in mathematics for seriating timed segments.

Grade two children also spent considerable time drawing place-value tables on squared paper in preparation for practice exercises. Though the tables proved useful in helping the children develop and practice place-value and arithmetic skills, an inordinate amount of time was required in setting out their work.

One of the causes involved prior instructions cautioning students to be very accurate in their drawing and writing. In this case such behavior greatly reduced the time remaining for arithmetic skill practice--the primary objective of the lesson. Upper-grade children, who had developed greater dexterity, had little difficulty setting out their exercises on squared paper.

Unless children can be encouraged to sketch the place-value tables more quickly (even at the expense of accuracy), the use of consumable worksheets should be considered for number work in the lower grades. A small booklet of worksheets (approximately 64 pages) could be produced locally and supplied to

each child in rural schools. Urban schools could duplicate the worksheets at the school site minimizing cost and distribution problems.

Grade four students were asked to cut out 45 squared paper multiplication blocks. These materials took from one to four class periods to prepare. Though they were used for several lessons and in general proved useful in developing and practicing the multiplication table, the time required to actually produce the aid seems unjustified. The aid could be easily produced at the Department of Education Materials Production Center and distributed to schools for use as flash cards.

In grade six a similar problem occurred with the production of place-value number cards. Again these materials proved to be useful aids but the time required to construct them did not seem justified.

Classroom produced learning aids can be extremely useful in teaching difficult concepts. The time and expense involved in their construction, however, must be balanced against potential utility. If the aid is to be used in only one lesson, preparation time must be reasonable or at least construction must take place outside of class-time.

Classroom Management: Several teachers initially experienced difficulty distributing aids and materials during the lessons. The process required an excessive amount of class-time during the first two weeks. The situation improved considerably when teachers began to give students the responsibility for distributing materials while they prepared the board for the lesson introduction.

If teachers work in one room (the normal situation) as opposed to dividing their attention between three classrooms as was called for in the current study, the materials could be stored in the classroom. Monitors could be assigned to distribute aids and materials at the appropriate times.

Simple manila envelopes helped keep the student sets of base-10 materials and similar aids organized for easy distribution. Materials of this type could be mailed directly to schools in their storage envelopes. Storage will continue to be a problem in bush schools because of the damp climatic conditions. A water-tight plastic container would go far in protecting the cardboard aids.

Teachers also had difficulty organizing for small-group instruction. Group work (two to six students) seemed to be an effective means of engaging children in skill practice games and concrete experiences with learning aids. Teachers initially experienced some difficulty effecting the transition between the large group lesson introduction and subsequent small group follow-up activity.

Teachers often attempted to introduce an activity with the children already broken into groups. This situation frequently caused confusion since the groups lacked understanding as to how to proceed. The teacher then had to give basic instructions to each group in turn. This process caused considerable disruption as groups waited for instructions from the teacher.

The problems were alleviated by suggesting that the teacher consistently begin each lesson with a large group demonstration involving the entire class working through the same exercise or game together. When most of the

children demonstrated an ability to carry out the process on their own, the class then broke into groups with a leader appointed at each to distribute materials.

The teacher then visited each group starting with those that experienced the greatest difficulties in the past. If general problems became apparent the teacher once again reassembled the whole class for a demonstration to clarify the situation. At the end of the lesson, the whole class reviewed the day's progress. A simple three-step plan emerged:

1. Whole-class demonstration--all students engaged in the same activity.
2. Small groups formed after the majority demonstrate understanding of procedures--groups work on the game, activity or exercise. Students work independently if warranted by activity. Teacher reinitiates whole-class discussion if general problems arise.
3. Whole-class review at the end of period.

One major oversight with regard to instructional materials involved difficulties experienced by teachers in displaying appropriate manipulations of the learning aids during whole-class demonstrations. Teachers made do with sketches on the chalkboard but the process of sketching base-10 models for number operations was time-consuming and somewhat more abstract than the actual concrete manipulations.

Attempts to alleviate this problem resulted in the introduction of a magnetic display board. A piece of galvanized sheet-steel (50 cm x 100 cm) painted with green chalkboard paint offered an excellent surface on which to

chalk place-value tables and manipulate magnetized base-10 materials, coins and other aids. One or more small pieces of rubber magnet strip removed from the gasket of an old refrigerator door was glued to each cardboard piece.

The display stands on the chalkboard tray. Place-value tables can be drawn on the chalkboard next to the display to carry out the corresponding symbolic manipulations. (See Figure 3.) If sheet steel is not available, the side of a metal cabinet can be painted and positioned next to the chalkboard. We found this system to be a most useful and inexpensive visual aid wherever old refrigerators and sheet metal can be found locally.

Insert Figure 3 about here.

Overall the activities and instructional aids were well received by the teachers and effectively utilized by the students. The reasonable production and shipping costs associated with the materials should keep initial investment and replacement within limited budget constraints. The die-cut cardboard manufacturing technique should have a wide application in other subject areas as well. A stencil map of Papua New Guinea has already been approved for trial distribution.

Die-cut cardboard aids along with a magnetic display board provide an inexpensive, versatile visual display system for classrooms even in the most remote regions of the country. It is important that all instructional materials be supplied with a simple teachers guide keyed to the course syllabus. The guide should be prepared with the idea that it will be used by

inspectors, headmasters, senior teachers and curriculum personnel as a basis for inservice instruction for practicing teachers.

Finally a general problem encountered by many of the teachers involved ongoing evaluation of individual student progress. Formal and informal assessment of student achievement varied across sites. With the possible exception of the WHP teacher, the teachers were far from consistent in their efforts to determine the success of individual children in meeting lesson objectives. The teachers generally characterized a successful lesson as one that progressed smoothly and in which all of the material was "covered."

Teachers seemed to interpret chorused responses from the class as appropriate measures of understanding. Rarely were individual students asked to respond to specific designated questions. Few criterion-referenced tests were administered by the teachers. Term tests were set about four times each year in order to compare overall achievement. The results seemed to serve primarily as a means of categorizing or ranking children, especially in the upper grades. They were rarely used as an aid in determining what specific skills individual students were lacking, as a basis for altering instruction, or as a criteria for forming appropriate instructional groups.

Clearly a series of brief (5 to 8 exercises) criterion-referenced tests should be included in any planned textbook. The tests should appear in the text and be administered every week or two. They should be designed in such a manner as to encourage the teacher to use the results in planning future instructions. A simple record-keeping system should be described in the teacher's guide to help teachers keep track of individual student progress.

Topic or term tests could also be included offering broader indicators of achievement and placement. Because of the difficulty in analyzing the larger number of items and the length of time between setting for these term exams, it is unlikely that the results can be effectively used to benefit individual understanding of mathematics. It would be inappropriate, in our estimation, to attempt to use topic or term tests for the purpose of making class-level instructional decisions.

Subject Matter: Based on the results of our observation several changes in the current community school syllabus seem advisable. First, we feel strongly that the current stress on multibase arithmetic is inappropriate. Conceding that Dienes' multiple representation model has considerable theoretical support when applied under ideal instructional conditions, we contend that its application to actual classroom use has met with little objective success in Papua New Guinea.

Misunderstandings regarding the purpose of multibase arithmetic abound. Those teachers who possess a good grasp of the methodology often treat each base as a mastery objective rather than as interim steps leading to base-10 operations.

Aside from the argument as to whether the method is effective in teaching computation, the fact remains that the multibase blocks necessary to effectively implement the program are all for intents and purposes "extinct" in Papua New Guinea. The current practice of substituting the more symbolic reresentation of exchange games using sticks, leaves, stones and shells is at best a poor substitute and at worst may simple increase the already overwhelming amount of disconnected school talk to be memorized.

We suggest as an alternative the development of numeration focusing almost exclusively on base-10 operations with perhaps traditional base-3 and base-5 exchange activities introduced early in the development of place-value. Number and counting should be introduced using body and tally counting systems indigenous to Papua New Guinea. Structured base-10 materials (die-cut cards or locally produced alternatives), coins and squared paper activities provide the necessary developmental transition to symbolic arithmetic.

All algorithms should be developed with consistent reference to place-value and regrouping. This process should provide adaquate basis for whole number and decimal work (Souviney, Keyser and Sarver, 1978). Ratio fractions should be introduced to provide the necessary language for defining partioning, equivalent families and the introduction to decimals. Operations with ratio fractions should be kept to a minimum (addition and subtraction with like denominators, multiplication and division of a fraction by a whole number).

We also recommend a change in emphasis for the development of set-theoretic and relational concepts. Rather than focusing on the underlying class or logical structures we suggest the curriculum directly address the surface language behaviors (English vocabulary and grammar) necessary for effective communication in mathematics. This suggestion is more a change in perspective than content. We envision employing activities similar to those in the current curriculum used for developing relational concepts of comparing, ordering, classifying and predicting. The difference lies with the manner in which the teacher describes the purpose of these experiences to himself and to his students.

The objective becomes one of developing language skills (the value of which is already appreciated by the teacher and students) as opposed to making explicit the ideas underlying the logical structure itself (e.g. clock games as models for cyclic groups).

Measurement and geometry seem fairly well developed in the current curriculum. The introduction of metric units should be coordinated with the science syllabus and should be phased in during grades four, five and six. Comparison activities should be used to introduce each measurement attribute (length, area, volume, weight, time, temperature, speed).

Arbitrary units of measure (either school-based or traditional units) should be used to extend the notion of measurement beyond comparison and ordering. Finally metric units should be introduced as standard units of measure (Keyser and Souviney, 1980; Hughes, 1981). For practical purposes liter measures of volume are preferred over cubic units (e.g., cm3, m3). We also feel the benefits of making a distinction between mass and weight is probably not worth the effort at this level. We suggest simply using the term weight throughout.

Geometry should progress from topological concepts such as inside and ouside to enclosed polygons, shapes, tesselations and patterns, the study of triangles and parallels, solid figures and the conventions of perspective drawing. This latter topic has received considerable attention in Papua New Guinea (Bishop, 1979; Lean and Clements, 1980) and should be an important objective associated with geometry instruction in grades four through eight.

The final strand which should be represented throughout the syllabus is problem solving applications. Application problems are characterized by relevance to everyday life and generally involve bringing one or more well-defined measurement or number operations to bear on elements given in the problem solving description.

Often we describe the problem in story form where all the necessary information is embedded in the vocabulary and the language structrure. The ability to solve story problems is closely tied to language skills. Other times data must be extracted from the environment in order to effect a solution. Of the five strands, none are as important or as poorly understood as problem solving. A three step process should be employed to assist children with solving application word problems:

Step 1. Give the solution to a story problem and ask the student to identify the phrase that indicates what operation to use.

Problem: Venna has 6 toea. Hai has 10 toea. How much money do they have altogether?

Hint: You need to add to solve this problem. What word(s) tell you to add?

Answer: How much altogether?

Step 2. Ask the student to determine what operation to use to solve a problem without actually computing the answer.

Problem: Twelve people want to go to Loloata Island. Each canoe carries only 4 people. How many canoes are needed for the trip?

Answer: Divide.

Step 3. Have the students solve the word problem using the information provided.

Problem: A truck can carry 750 kilograms of cargo. A bag of coffee weighs 50 kilograms. How many coffee bags can the truck carry?

Answer: 750/50 = 15 bags.

Other possible variations include writing problems with no numbers and ask the students to tell what operation(s) are required to solve the problem. Also problems can be written with blanks for the student to fill and then solve. Each of these examples help children focus on the language used to define a problem setting. Once the student understands what the problem is asking, it is a relatively easy task to complete the required computations.

Beginning problems should be designed to be solved in one operation, with all the necessary information included. Later, problems requiring two or more operations can be attempted. Extra information not used in the solution should be included later as a distractor. Problems should be drawn from all the content strands: number and operations, measurement, geometry.

Word problems represent only one limited catagory of problem appropriate for elementary aged children. More divergent problem situations require more robust strategies such as conducting and experiment, organizing data, looking for patterns and functions and reducing to a simpler case (Souviney, 1981)

Textbook Production

Our results indicate that the teachers involved in the study were capable

of effectively coordinating student activity books and learning aids. There were, however, definite limits as to the number of elements the children were capable of managing efficiently. The teaching suggestions provided for each lesson were used by all the teachers on a daily basis for programming purposes and during the lesson implementation. Teachers generally praised the specific hints and suggestions though there was a consistent request for more worked examples.

Some confusion seemed to be caused by our attempt to provide complete step-by-step instructions for each lesson. For example in one exercise the numbered steps for the teacher did not correspond with the student exercise numbers. One teacher read the instructions verbatim to the class. For example: "Number one. Look at your worksheet. Number two. How many fish does the man have?" The children looked at worksheet problem number two instead of problem number one. They were confused, along with the teacher, for the remainder of the lesson. Though only one of the five teachers experienced this difficulty, the example points out the problems associated with writing a teaching "script" that, when read to the children without interpretation, conveys the appropriate meaning.

Though we were not attempting to "teacher proof" the lessons, our experience suggests that the curriculum writer must get into the playwrite business in a big way, or avoid giving the impression that the carefully sequenced set of instructions must be followed precisely. Clusters of directions addressing critical sub-elements of lesson procedures might be more appropriate. Subsequent synthesis of these key elements is then left to the teacher's judgment. Attempting to circumvent the teacher in such matters has, time and time again, been shown to be unsuccessful. Sets of written

instructions cannot substitute for good inservice education and teaching experience.

From our experience it seems clear that teachers and children, even from the most remote sites, would benefit greatly from the prompt introduction of an appropriate mathematics textbook. The content should reflect the rich cultural heritage of Papua New Guinea and address concepts which will be required for life in this rapidly developing nation. It seems vital that students be prepared to contribute effectively to village development should they not be selected to go on to secondary school. Likewise the needs of the growing percentage of children who are privileged to continue their education cannot be ignored.

Kuperus (1980) concludes from work carried out in Cameroon, Africa, that since the vast majority of children in developing countries terminate their formal education after five or six years, the entire enterprise must be geared to preparing children for effective social and economic participation at the village level. Though stress must be placed on functional mathematics literacy, sufficient structure must also be present in the development of the content to support subsequent mathematical instruction necessary for commerce and secondary education.

Though it is vitally important to incorporate relevant features of community development into primary mathematics education (e.g., designing and constructing rain water tanks, planning a trade store business, book-keeping for cash crops such as copra, cocoa, coffee, tea) these functional aspects of mathematical application are not sufficient in themselves to constitute a mathematical curriculum. The functional activities would form a collection of

unrelated ideas without some attention being paid to the underlying structure of number and measurement systems, regularities and patterns found in computation and geometry and the powerful medium of commuication and prediction offered by graphs and statistics. Clearly the issue of poor application problem solving skills will remain unaddressed by a curriculum comprised exclusively of functional applications.

Alternately, a program of instruction which selects activities exclusively on the basis of elucidating the underlying logic and structure of the mathematical content seems totally unacceptable. Not only will the resulting knowledge be virtually untransferrable to the village development setting, without a real world context precious little learning is likely to take place at all.

In general, relevant education literature from several developing nations, indicates that the introduction of appropriate textbooks has a significant effect on mathematics achievement (Comber and Keeves, 1973; Skukla, 1974; Walker, 1976; Castro and Sanguinetty, 1977). The introduction of locally produced texts seems particularly important in the Papua New Guinea context.

Wilson (1973) reported that one of the primary successes associated with the implementation of locally produced curriculum materials in the Caribbean region was the vehicle it provided for inservice training. Many of the teachers involved in the development, trialling and implementation of the secondary text materials experienced significant long term changes in their own classroom behaviors.

Based on such a philosophy, curriculum development in Papua New Guinea would serve the dual purpose of providing much needed instructional materials at an affordable cost as well as upgrading the qualifications of the teachers involved. Though the number of teachers participating initially might seem insignificant (say 20 teachers per grade level), when teachers employed in the trialling of materials are included as much as 10% of the teaching force could be directly involved. This process has the added advantage of ensuring a higher rate of acceptance once final implementation is underway.

Conclusions

The following conclusions are based on our analysis of the implementation effort and testing results.

1. Mathematics and language achievement varied significantly between the five schools tested.

2. Grade two children exhibited mathematical achievement gains twice those for grades four and six.

3. The variance associated with mathematics achievement scores diminished over the trialling period indicating that the student with low scores initially experience larger gains in achievement scores than their higher scoring peers.

4. Measures of English reading ability and cognitive development were highly correlated with mathematics achievement, especially in grade six.

5. On the average students correctly answered 63% of the appropriate grade level objectives. The percent is somewhat higher for grade two, decreasing for grades four and six.

6. On the average 34% of the students tested attained a mastery level of 80% correct responses on grade level objectives. The percent is somewhat higher in grade two, decreasing for grades four and six.

7. Students exhibited substantially higher levels of achievement relative to computation, measurement and mathematical language than problem solving applications.

8. Highly perceptual concrete materials wereare useful in developing key number and operation, measurement and classification concepts. Only materials that are actually available in the vast majority of the classrooms should be incorporated in future textbooks and teacher handbooks.

9. Examples of counting systems and traditional measurement techniques indigenous to Papua New Guinea should be incorporated into the introductions of appropriate concepts in number and operations, measurement and geometry.

10. A three step instructional procedure - concrete model, pictorial representation, symbolic manipulation - was effectively employed by project teachers when introducing number and operation concepts. The technique should stress place-value as a unifying concept and focus on base-10 operations.

11. The inclusion of multibase arithmetic in the Primary syllabus is not

required for the effective development of base-10 computation skills. Without the availability of multibase blocks, its inclusion may even be detrimental to the eventual development of arithmetic skills.

12. Student activity books were effectively used in the project classrooms. Teachers and students would benefit from the prompt introduction of an appropriate student textbook.

13. The teachers involved in the study were able to benefit sufficiently from a two-week inservice course to effectively implement student activity books and learning aids adapted from the current Mathematics for Community Schools program.

14. The brief inservice course was effective primarially because it focused on implementing specific curriculum products as opposed to addressing general pedagogical and subject matter competencies.

15. A knowledgeable individual at each school (teacher and/or observer), directly responsible for the mathematics curriculum materials, significantly contributed to the effectiveness of the implementation effort.

16. An efficient line of communication between provincial and national curriculum officers and teachers in the field contributed significantly to the effectiveness of the implementation effort.

17. The involvement of practicing classroom teachers throughout the curriculum development exercise greatly simplified the implementation of the final product. The more teachers can be involved in the writing, trialling

and inservice aspects of the project, the greater acceptance the product will receive once it reaches the classroom.

18. Project teachers in general exhibited limited abilities in evaluating student progress. Those tests that were administered by the teachers were used to order students for the purpose of grading and selection. The information was rarely used to assess individual student needs and make subsequent instructional decisions. Frequent criterion-referenced tests should be incorporated into future texts along with clear instructions on interpreting the results to assist with grouping students for revision and enrichment work.

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TABLE 1

SITE CHARACTERISTICS

Site	Stud. N. Tot	% Fem.	% Cohort in Sch.	Classrooms			Teachers (n)	Experience $\bar{x}$ Yrs.	Elec.	Tele.	Duplicator	Min. Cost to POE (r.t.)	Hours to POE (r.t.)
				Perm.	Bush	Tot.							
MP	90	43	61	3	0	3	2	10.5	N	N	N	K 10.00	6 (canoe)
WSP	126	28	62	0	6	6	5	3.8	N	N	N	K125.00	6 (foot & air)
SHP	291	47	51	7	2	9	8	4.5	N	N	N	K 8.00	4 (PMV)
WHP	233	48	45	5	3	8	8	5.6	N	Y	Y	K 2.00	1 (PMV)
NCD	408	45	62	12	0	12	11	6.9	Y	Y	Y	K 1.20	0.5 (PMV)
$\bar{X}$	230	42	56	5.4	2.2	7.6	6.8	5.6	N/A	N/A	N/A	K 29.24	3.5

POE– Provincial Office of Education
MP – Manus Province
WSP– West Sepik Province
SHP– Southern Highlands Province
WHP– Western Highlands Province
NCD– National Capital District

TABLE 2

SUBJECT AGES

Grade	2		4		6		Control			Total Site	
Site	n	$\bar{X}$ age	n	$\bar{X}$ age	n	$\bar{X}$ age	Gr.	n	$\bar{X}$ age	n	$\bar{X}$ age
MP	N/A	N/A	22	12.5	29	13.3	N/A	N/A	N/A	90	11.2
WSP	26	11.0	28	10.9	23	14.6	2	30	9.9	126	11.3
SHP	34	9.2	32	10.2	33	14.4	2	35	8.3	285	9.7
WHP	21	7.6	45	10.9	23	12.3	6	21	12.5	233	10.0
NCD	41	8.5	36	11.3	36	12.2	4	38	11.3	408	9.7
$\bar{X}$	30.5	9.1	32.6	11.1	28.8	13.3	3.5	31	10.3	228.4	10.1

$\bar{X}_{age}$ = mean age
n = number of students

TABLE 3

POOLED GRADE FOUR AND SIX MEAN ACHIEVEMENT BY SCHOOL (%)

Site	PMAT2	PMAT3	PMAT4	READ	DICT	n_{pmat2}
MP	60.7	65.1	64.6	85.3	88.0	52
WSP	51.9	59.0	61.0	75.3	89.7	52
SHP	65.7	68.7	70.7	83.5	88.3	65
WHP	53.3	56.7	59.1	74.1	74.6	67
NCD	59.8	61.7	63.5	86.0	86.6	64
$\bar{X}$	58.3	62.4	63.8	80.8	85.4	60

MP = Manus Province
WSP = West Sepik Province
SHP = Southern Highlands Province
WHP = Western Highlands Province
NCD = National Capital District

PMAT2 = pre-test
PMAT3 = post-test
PMAT4 = retention-test
READ = sentence completion test
DICT = oral dictation test

TABLE 4

MEAN ACHIEVEMENT BY GRADE

Grade	PMAT2	PMAT3	PMAT4	READ	DICT	n_{pmat2}
2	30.1	36.9	38.4	47.3	24.9	114
4	52.6	55.7	56.8	74.9	81.1	157
6	64.3	68.8	71.1	86.3	89.3	143
$\bar{X}$	50.4	54.6	56.9	75.3	72.8	138
SD	17.2	16.0	16.5	19.5	27.9	

SD = standard deviation

TABLE 5

ITEM ANALYSIS BY CONTENT STRAND PMAT2 AND PMAT3

Content Strand	Grade							
	2		4		6		$\bar{X}$ pool	
	PMAT2 (%)	PMAT3 (%)	PMAT2 (%)	PMAT3 (%)	PMAT2 (%)	PMAT3 (%)	PMAT2 (%)	PMAT3 (%)
Measurement	49	58	70	78	83	85	71	74
Number and Operations	32	41	60	65	73	81	56	63
Mathematical Language	46	53	70	75	78	83	66	71
Problem Solving Applications	0.1	0.1	6	4	18	18	9	8
$\bar{X}_T$	30	37	53	56	64	69	50	55

$\bar{X}_{pool}$ = mean grades 2, 4 and 6.

$\bar{X}_T$ = mean across all strands.

TABLE 6

ACHIEVEMENT SCORES FOR COMMUNITY AND INTERNATIONAL PRIMARY SCHOOLS PMAT4 AND READING (%)

Years of Schooling	PMAT4[3]		READING[3]	
	INT[1]	PNG[2]	INT	PNG
4	61.3	56.8	94.4	74.9
6	77.7	71.1	98.5	86.4
$\bar{X}$	69.5	64.0	96.5	80.7

1. International Primary School – grades 3 and 5 plus one year preparatory.
2. Community School sites – grades 4 and 6.
3. PMAT4 and READING administered eight months after the start of school for INT and PNG.

TABLE 7

ACHIEVEMENT SCORES FOR US ELEMENTARY AND PNG COMMUNITY SCHOOLS
PMAT 2 (%)

Years of Schooling	PMAT2[3] US[1]	PMAT2[3] PNG[2]
4	59.9	52.6
6	78.1	64.3
$\bar{X}$	69.0	58.5

1. United States site – grades 3 and 5 plus one year kindergarten.
2. Community School sites - grade 4 and 6.
3. PMAT2 was administered five months after the start of school for US and PNG students.

TABLE 8

CORRELATION OF MATHEMATICS ACHIEVEMENT WITH SIX COGNITIVE, MEMORY AND LANGUAGE MEASURES

Grade Level	COGTO (r)	VM1 (r)	VM2 (r)	MS (r)	READ (r)	DICT (r)	PMAT2 ($\bar{X}$ %)
2	0.38	0.33	0.24	0.25	0.26	0.32	29 6
4	0.39	0.10	0.15	0.09	0.60	0 37	52.7
6	0.61	0.25	0.05	0.45	0.58	0 53	65.3
$\bar{X}_{total}$	0 63	0.28	0.22	0.42	0.76	0.80	50.9

r = pearson-product correlation coefficient.

Figure 1

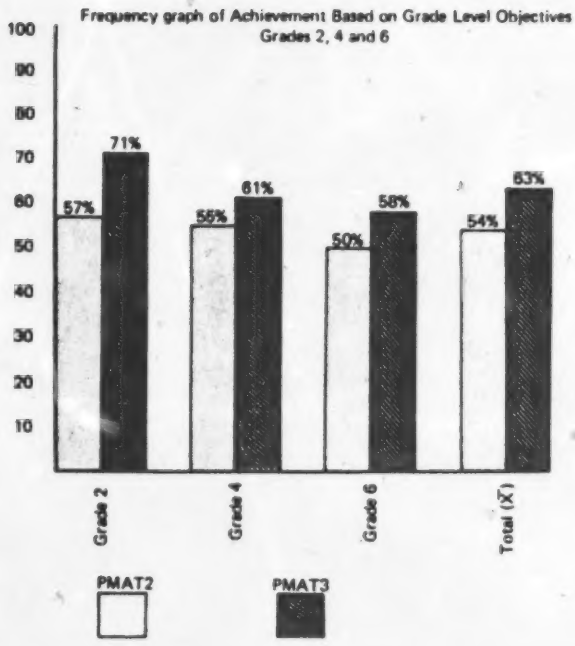

Figure 2

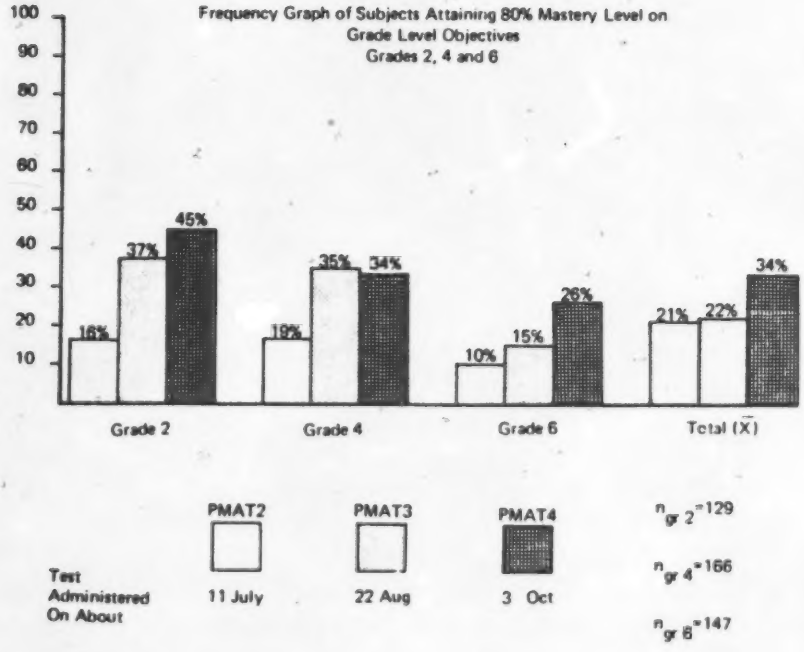

Figure 3

Magnetic Display Board